APPLICATION

FOR

UNITED STATES LETTERS PATENT

TITLE: DIGITAL EXPOSURE CIRCUIT FOR AN IMAGE SENSOR

APPLICANT: ERIC R. FOSSUM; ALEXANDER I. KRYMSKI; ROGER A. PANICACCI AND CHRISTOHER CLARK

"EXPRESS MAIL" Mailing Label Number EL 339814622US
Date of Deposit 4-23-99
I hereby certify under 37 CFR 1.10 that this correspondence is being deposited with the United States Postal Service as **"Express Mail Post Office To Addressee"** with sufficient postage on the date indicated above and is addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231.

Deborah

Deborah Dean

PATENT
ATTORNEY DOCKET NO: 08305/035001/98-05

DIGITAL EXPOSURE CIRCUIT FOR AN IMAGE SENSOR

Cross Reference to Related Applications

This application claims the benefit of the U.S. Provisional Application No. 60/082,793, filed on April 23, 1998.

Background of the Invention

CMOS active pixel sensors represent a digital solution to obtaining an image of an impinging scene. CMOS technology enables integrating electronics associated with the image sensing onto the chip. This includes, for example, one or more analog-to-digital converters on the chip, as well as timing and control circuitry.

One important feature of a well-defined image is an amount of exposure. Some cameras include automatic gain and exposure control. The automatic gain and exposure control determines if the image is underexposed or overexposed, and can adjust some

feature of the image acquisition to correct the exposure amount.

Existing CCD cameras select the exposure time based on some feature of the scene being imaged. Some cameras, for example, compute the average intensity over the entire pixel array. Other cameras compute the average intensity over a central area of the CCD. The average is often calculated by a digital signal processor which is separate from the CCD chip.

Summary of the Invention

The present system teaches a programmable threshold indicator based on accumulated and programmable measurements of image pieces. The digital image data stream is analyzed by the counting the number of samples within a given interval of intensities to form information indicating an image histogram. The sample count is compared with programmable thresholds.

Brief Description of the Drawing

FIG. 1 shows a basic block diagram;

FIG. 2 shows a flowchart of operation of a two-threshold embodiment;

FIG. 3 shows a point diagram of the FIG. 2 embodiment;

FIG. 4 shows a flowchart of a second, three-threshold embodiment;

FIG. 5 shows a point chart;

FIG. 6 shows exemplary circuitry for carrying out this embodiment; and

FIG. 7 shows results of simulation.

Description of the Preferred Embodiments

The inventors recognize that in some particular images, exposure control by simply computing the average of the image could produce disadvantageous results. For example, consider a scene of black and white stripes. Fifty percent of the image could be very bright, and the other fifty percent could be completely dark. The average is fifty percent which could be considered the correct exposure. Both image portions from the bright scene and the dark scene, however, could be poor.

The present system provides a programmable threshold indicator based on measurements of various portions of the image. A block diagram of the system is shown in Figure 1.

Active pixel image sensor 100 includes an array of units, e.g., rows and columns, of CMOS active pixels. Each preferably includes an in-pixel buffer transistor configured as a source follower, and an in-pixel row or column select transistor. The output of the sensor can be provided either single pixel at a time, or as a parallel group of pixel units 102 to the analog-to-digital converter 104. ADC 104 preferably produces an 8-bit output 106. The two to three most-significant bits of the analog-to-digital converter are usually enough to analyze intensity distribution.

The three most-significant bits 108 are coupled to pixel characterization elements 110. These detect whether the states of the three bit output 108 have a specified characteristics. When the states have the specified characteristics, the decoder produces an output. Counters 112 count the output, effectively counting the number of times that the bits are coincident with

the values. Therefore, the counters 112 keep a count, for each frame, of the number of samples which have specified values.

A number of thresholds are maintained by I/O register 114. Comparing elements 116 compare the counter outputs with the thresholds from the interface register. If one or more of these thresholds are exceeded, then decision block 118 produces a command to either increment or decrement the exposure: e.g., the shutter width or gain of image acquisition. This can be done frame by frame, or for a group of frames.

A first embodiment uses a two-threshold simple-scheme. This takes into account only the two most-significant bits. In this scheme, the relative number of data whose MsBs are " 11" are counted. The number of data in the lower half segment of the data scale (e.g. the most significant bit [MSB] is equal to 0) is also counted. The data " 11" is considered as being close to saturation. An exemplary threshold for the amount of that data can be thirty percent. Similarly, the tolerance for " dark" data, in which the MSB is zero, is restricted to be 75%. Step 202 detects if the first threshold in which both major bits are " 11" for more than thirty percent of the data. This is taken

as an overexposed condition at 204 and the integration time or gain is lowered. The second threshold is investigated at 210. If five percent of the data is dark (MSB is 0), the data is taken as underexposed data and the integration time or gain is increased.

The thresholds must be selected with an amount of hysteresis which is effective to avoid oscillations when the image has many contrasts i.e. between black and white. For example, the sum of the two percentages should exceed 100 percent.

FIG. 3 shows a bar graph with the overexposure/underexposure parameters. The point A in FIG. 3 is at an overexposed position. If more than 30 percent of the image is in this position, then the image is taken to be overexposed and the gain or integration time is lowered. Conversely, point B is in an underexposed position. If more than 75 percent of the image is in this position, then the image is taken to be underexposed.

A second embodiment which operates according to the flowchart of FIG. 4 uses a three threshold advance scheme. This takes only the two highest bits at the input to the indicator, as in the first system. However, this scheme uses three decoders

and three counters as shown in FIG. 1. This system counts: (a) the number of samples in which the upper bits are "11"; (b) the number of samples in which the most significant bit is "0"; and (c) the number of samples in which the upper bits are both "00". This provides more information about the image than the FIG. 2 system. This also enables adjusting the exposure/gain in two steps.

FIG. 4 shows a flowchart of the second embodiment. At step 410, the decision making process determines if the relative number of samples determined by a, in which both MsBs are "11" is more than 75 percent. If so, then the image is considered to be grossly overexposed. At step 406, the exposure/gain is decremented by a higher value H.

If the result of step 410 is No, step 420 tests if the relative number of samples is more than 30 percent. If so, the image is considered as being normally overexposed at 422. A tuning decrement T is applied at step 422 where T less than H.

If the relative number of sample c, the very dark pixels, is more than 75 percent at step 430, then the image is considered as

seriously underexposed. In this case, the exposure/gain is incremented by the higher value H at step 432.

Finally, if none of the other steps are true, the relative number of samples b, that is moderately dark pixels that are not very dark, are tested at 440. If this value is more than 75 percent detected at step 416, then the image is considered as moderately dark at 442. A tuning increment T is added to the exposure or gain.

This can be carried out on a frame by frame basis. These thresholds can also be programmable, to allow more bright or dark scenes. The programmable thresholds can be made by user manual intervention, or by an automatic intervention from the computer system.

FIG. 5 shows a bar chart showing the placement of the pixels within groups a, b, or c, similar to that in FIG. 3.

An example circuitry is shown in FIG. 6. It should be understood that this circuitry is exemplary only, and that other similar circuits could be easily formed using either a processor or hard wire gates using hardware definition language. Of

course, this operation could also be carried out using a programmed processor.

FIG. 7 shows results of a simulation using a simple test. The circuit signals maxed during the second frame as the number of 11 sample has exceeded 30 percent and min in the third frame as after two 00 counts has approached 75 percent of the total samples.

Although only a few embodiments have been disclosed above, other modifications are within the disclosed features.

For example, the system as described could be carried out using a processor or a digital signal processor. Preferably, however, all of the subjects in FIG. 1 are carried out on the same substrate.